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(54) **TRANSCRITICAL CARBON DIOXIDE REFRIGERATION SYSTEM WITH MULTIPLE EJECTORS**

(71) Applicant: **HEATCRAFT REFRIGERATION PRODUCTS LLC**, Richardson, TX (US)

(72) Inventor: **Augusto J. Pereira Zimmermann**, Stone Mountain, GA (US)

(73) Assignee: **Heatcraft Refrigeration Products LLC**, Richardson, TX (US)

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F25B 1/10	(2006.01)
F25B 5/00	(2006.01)
F25B 9/00	(2006.01)
F25B 41/00	(2006.01)

(52) **U.S. Cl.**

CPC ***F25D 3/12*** (2013.01); ***F25B 1/10*** (2013.01); ***F25B 5/00*** (2013.01); ***F25B 9/008*** (2013.01); ***F25B 41/00*** (2013.01); *F25B 2309/061* (2013.01); *F25B 2341/0012* (2013.01); *F25B 2341/0015* (2013.01); *F25B 2400/054* (2013.01); *F25B 2400/072* (2013.01); *F25B 2400/075* (2013.01)

(58) **Field of Classification Search**

CPC F25B 1/10; F25B 1/06; F25B 5/00; F25B 2341/0015; F25B 9/008; F25B 5/04; F25B 5/02; F25B 2400/075

See application file for complete search history.

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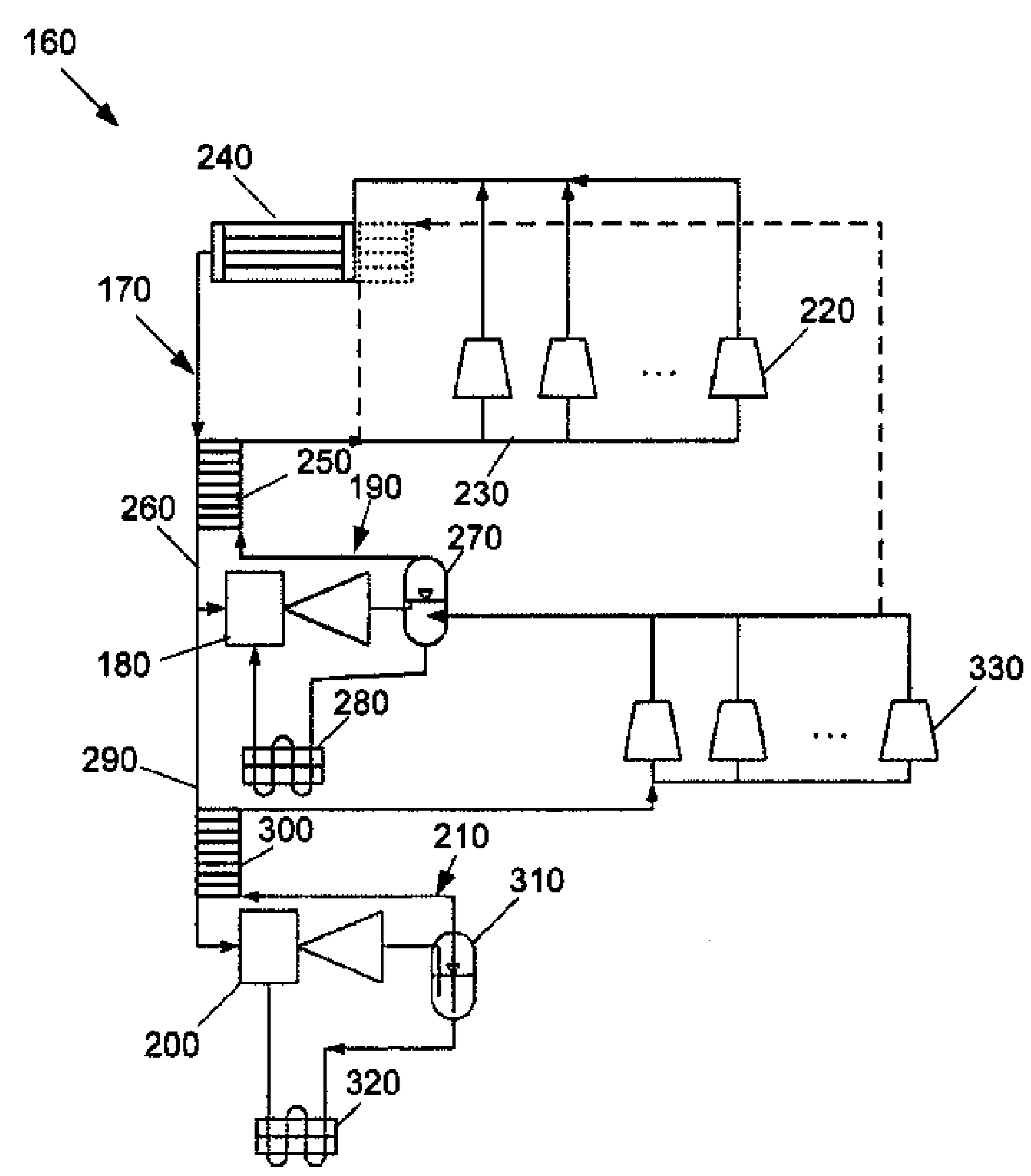
Primary Examiner — Elizabeth Martin

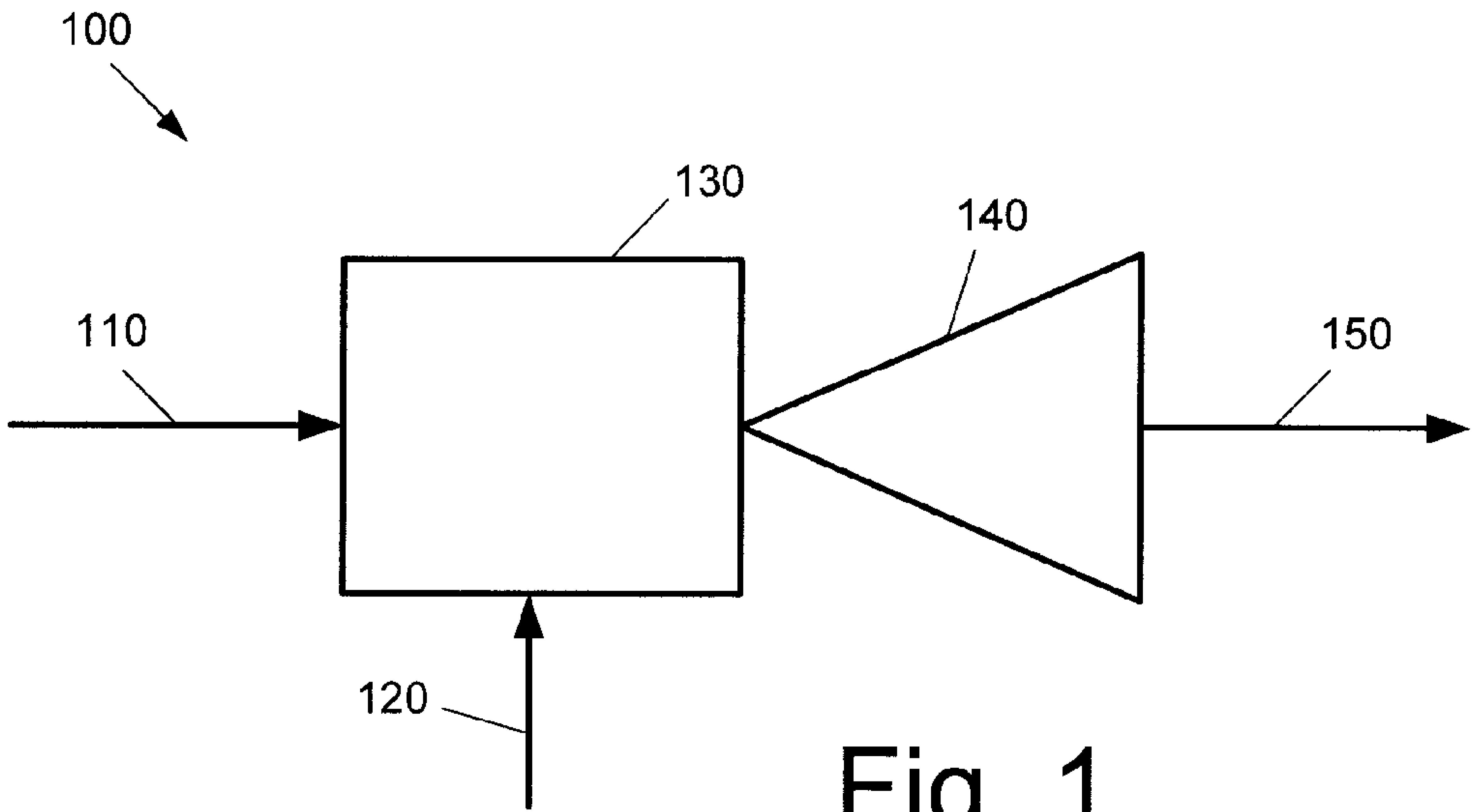
(74) *Attorney, Agent, or Firm* — Baker Botts L.L.P.

(57) **ABSTRACT**

The present application provides a carbon dioxide based refrigeration system. The carbon dioxide based refrigeration system may include a mid temperature cycle with a mid temperature ejector, a low temperature cycle with a low temperature ejector, and a gas cooler/condenser in communication with the mid temperature cycle and the low temperature cycle.

16 Claims, 4 Drawing Sheets

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130
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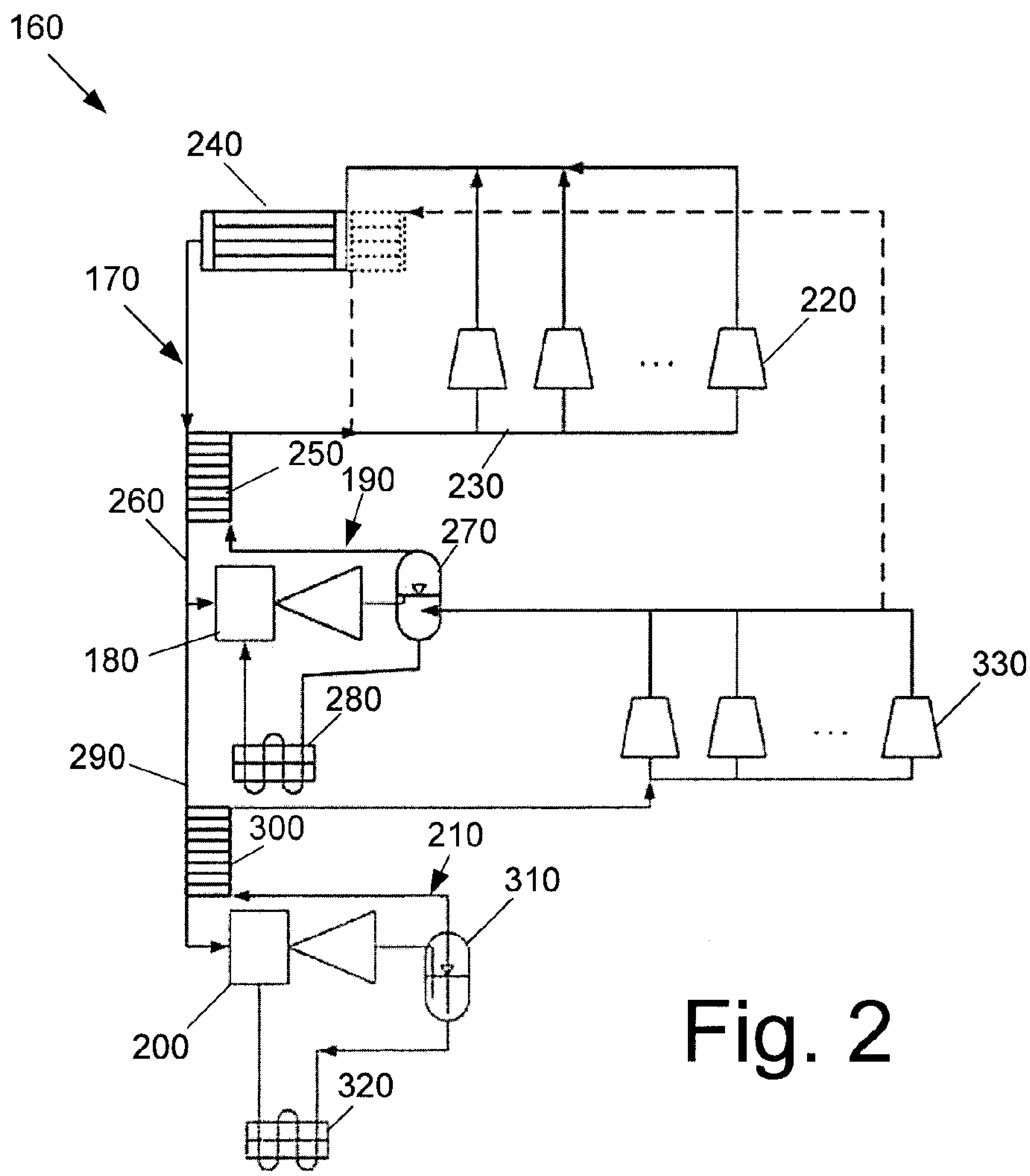
120

Fig. 1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200
320

Fig. 2

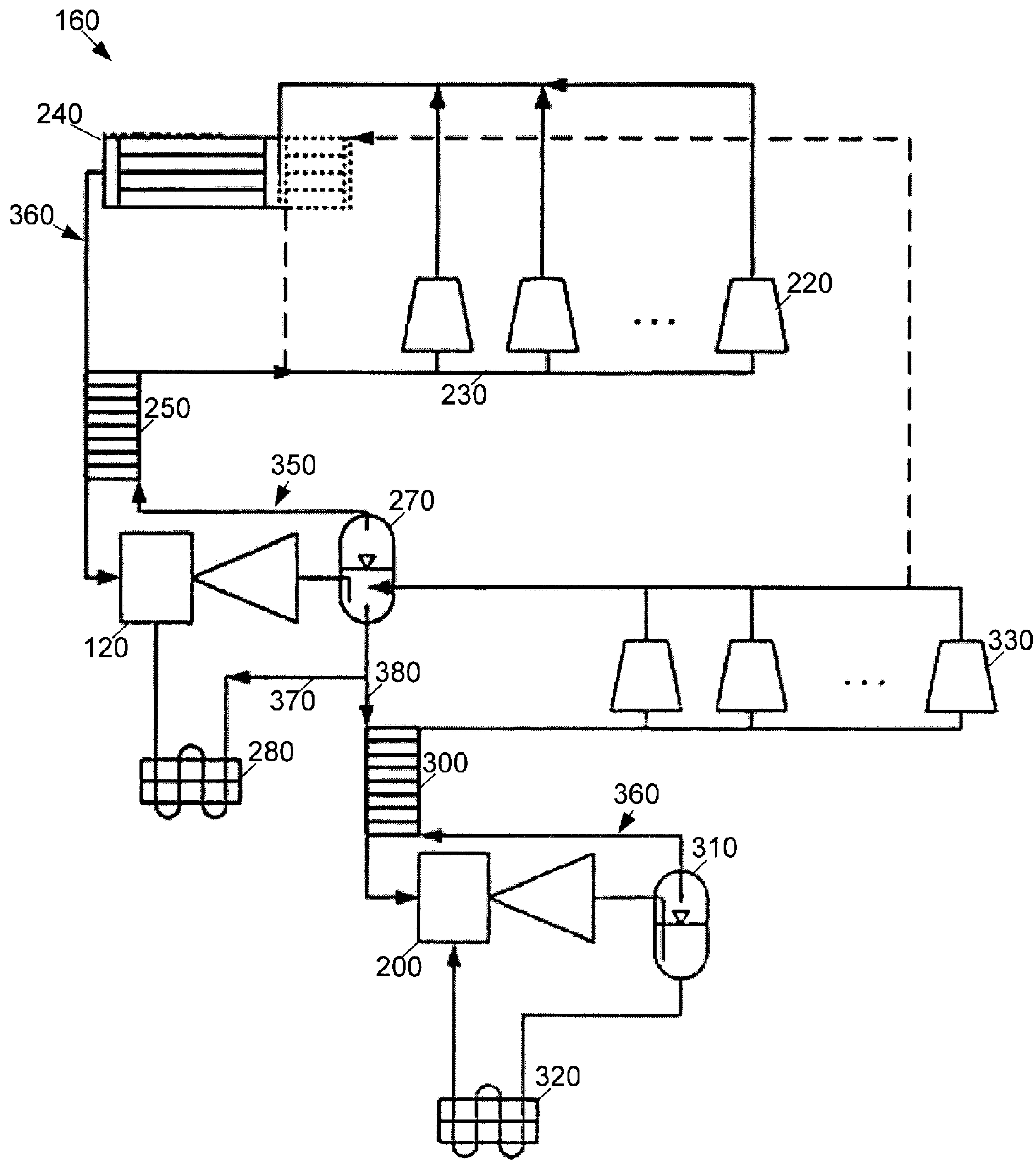
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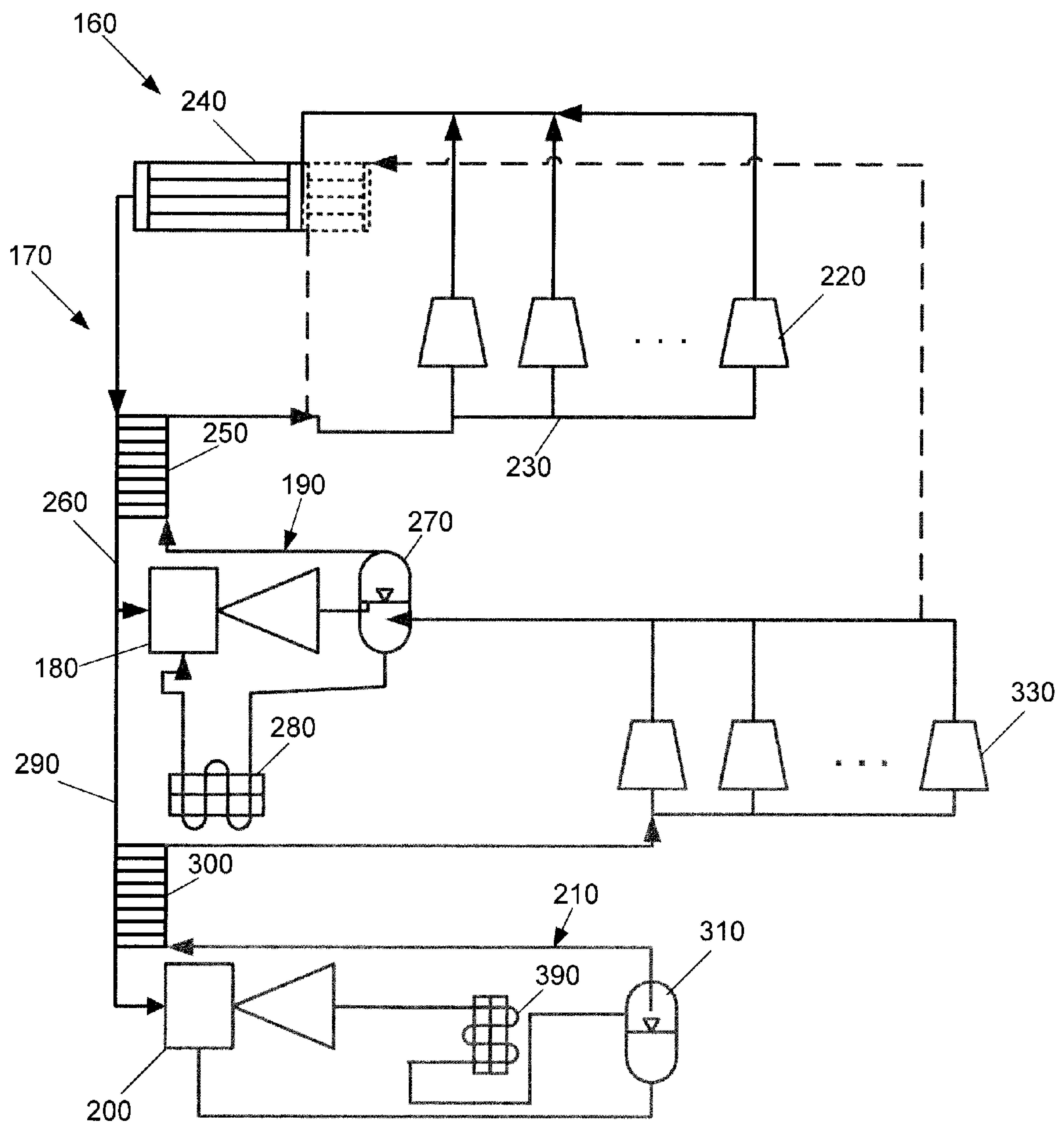
Fig. 3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210
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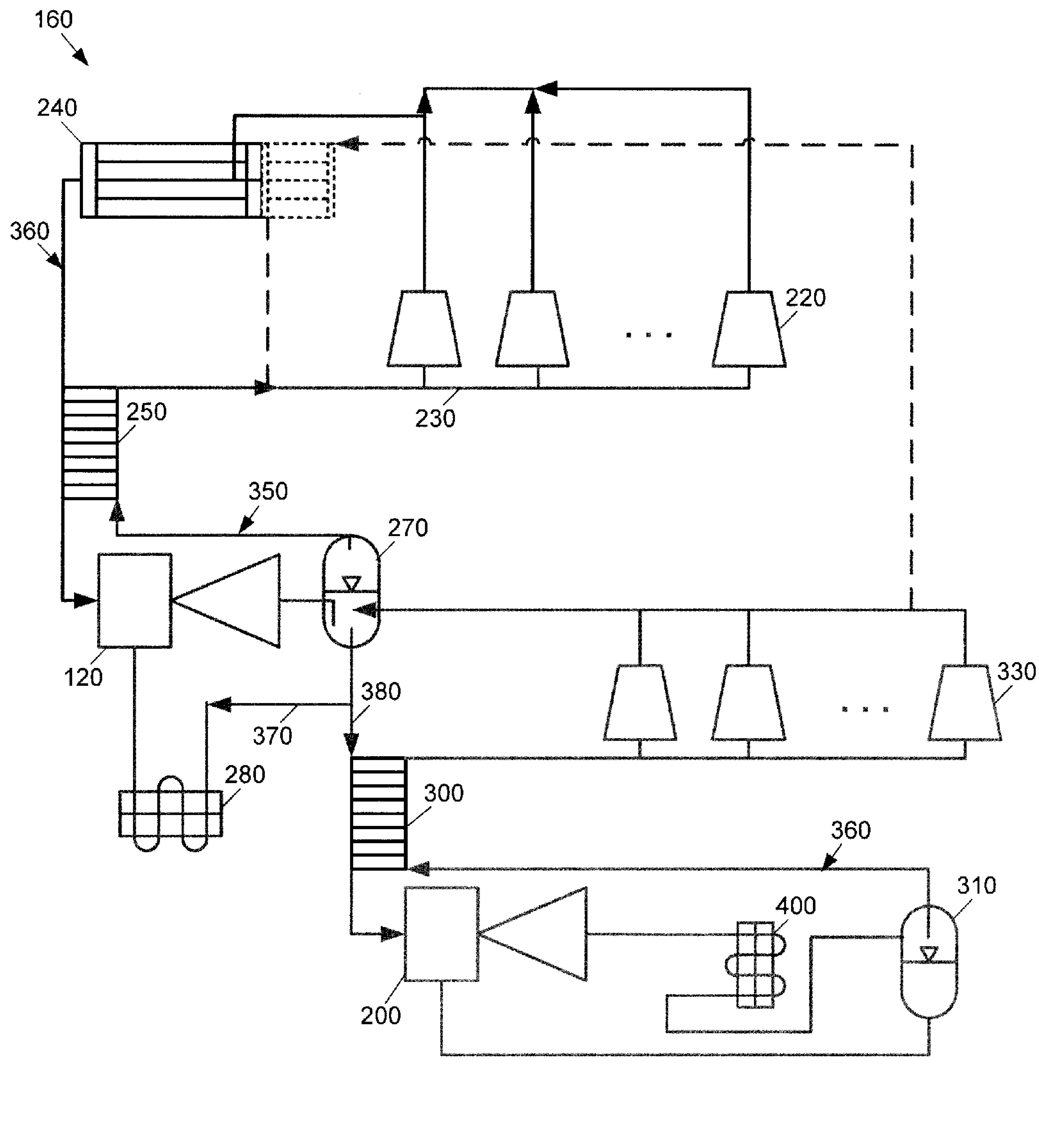
390
200

Fig. 4


160
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200

Fig. 5

TRANSCRITICAL CARBON DIOXIDE REFRIGERATION SYSTEM WITH MULTIPLE EJECTORS

TECHNICAL FIELD

The present application and the resultant patent relate generally to refrigeration systems and more particularly relate to a transcritical carbon dioxide refrigeration system using multiple ejectors at multiple temperatures for improved overall efficiency.

BACKGROUND OF THE INVENTION

Current refrigeration trends promote the use of carbon dioxide and other types of natural refrigerants as opposed to conventional hydrofluorocarbon based refrigerants. Although such carbon dioxide based refrigeration systems may be considered more environmentally friendly, such systems tend to be less efficient and, hence, may require more overall power usage given the low critical point and therefore high throttling losses between the heat rejection and heat absorption process in a conventional refrigeration cycle.

There is thus a desire for refrigeration systems using natural refrigerants such as carbon dioxide with improved efficiency and improved overall energy consumption. Preferably such an improved refrigeration system may be environmentally friendly with reduced overall operational and maintenance requirements.

SUMMARY OF THE INVENTION

The present application and the resultant patent thus provide a carbon dioxide based refrigeration system. The carbon dioxide based refrigeration system may include a mid temperature cycle with a mid temperature ejector, a low temperature cycle with a low temperature ejector, and a gas cooler/condenser in communication with the mid temperature cycle and the low temperature cycle.

The present application and the resultant patent further provide a method of operating a carbon dioxide based refrigeration system. The method may include the steps of flowing a first portion of a carbon dioxide refrigerant to a mid temperature ejector, accelerating the first portion of the flow of the carbon dioxide refrigerant in the mid temperature ejector, flowing the first portion of the flow of the carbon dioxide refrigerant to a mid temperature suction group, flowing a second portion of the carbon dioxide refrigerant to a low temperature ejector, accelerating the second portion of the flow of the carbon dioxide refrigerant in the low temperature ejector, and flowing the second portion of the flow of the carbon dioxide refrigerant to a low temperature suction group.

The present application and the resultant patent further provide a refrigeration system. The refrigeration system may include a flow of a carbon dioxide refrigerant, a mid temperature cycle with a mid temperature ejector, a low temperature cycle with a low temperature ejector and a gas cooler/condenser in communication with the mid temperature cycle, and the low temperature cycle. A first portion of the flow of the carbon dioxide refrigerant flows through the mid temperature cycle and a second portion of the flow of the carbon dioxide refrigerant flows through the low temperature cycle.

These and other features and improvements of the present application and the resultant patent will become apparent to

one of ordinary skill in the art upon review of the following detailed description when taken in conjunction with the several drawings and the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic diagram of an ejector described herein.

FIG. **2** is a schematic diagram of a transcritical carbon dioxide refrigeration system as may be described herein.

FIG. **3** is an alternative embodiment of a transcritical carbon dioxide refrigeration system as may be described herein.

FIG. **4** is an alternative embodiment of a transcritical carbon dioxide refrigeration system as may be described herein.

FIG. **5** is an alternative embodiment of a transcritical carbon dioxide refrigeration system as may be described herein.

DETAILED DESCRIPTION

Referring now to the drawings, in which like numerals refer to like elements throughout the several views, FIG. **1** shows an example of an ejector **100** as may be described herein. Generally described, the ejector **100** may be a mechanical device with or without any moving parts. Instead, the ejector **100** mixes two fluid streams based upon a momentum transfer between a motive fluid and a suction fluid. A motive inlet **110** may be in communication with a first flow under pressure. The ejector **100** also may include a suction inlet **120** in communication with a second flow. The ejector **100** also may include a mixing tube **130** and a diffuser **140**. The motive flow may be reduced in pressure as the suction flow is accelerated therein. The flows are mixed in the mixing tube **130** and flow through the diffuser **140** as a mixed flow. The mixed flow may be discharged at an outlet **150** at a pressure greater than the suction flow but less than the motive flow. The overall suction capability for the ejector **100** may be based upon the net positive suction head available therein. Other component and other configurations also may be used herein.

FIG. **2** shows an example of a carbon dioxide based refrigeration system **160** as may be described herein. The transcritical carbon dioxide based refrigeration system **160** may include a number of the ejectors **100** in a parallel configuration **170**. In this example, a medium temperature ejector **180** may be used in a medium temperature cycle **190** and a low temperature ejector **200** may be used in a low temperature cycle **210**. Other components and other configurations also may be used herein. As the names imply, the mid temperature cycle **190** and the low temperature cycle **210** operate at different temperatures.

The mid temperature cycle **190** may include any number of mid temperature suction groups **220** or compressors. The mid temperature suction groups **220** may be used herein in a parallel configuration or otherwise. The mid temperature suction groups **220** compress a flow of a carbon dioxide refrigerant **230**. Other types of refrigerant flows may be used herein. The carbon dioxide refrigerant **230** may be forwarded to a gas cooler/condenser **240**. The carbon dioxide refrigerant **230** may lose or reject heat in the gas cooler/condenser. The mid temperature cycle **190** also may include a mid temperature suction line heat exchanger **250**. The mid temperature suction line heat exchanger **250** may exchange heat between the flow of refrigerant **230** entering the mid temperature suction groups **220** and the flow of refrigerant

230 leaving the gas cooler/condenser **240**. Other components and other configurations also may be used herein.

A first portion **260** of the flow of refrigerant **230** leaving the gas cooler/condenser **240** may be directed to the mid temperature ejector **180**. The first portion **260** of the refrigerant flow **230** may be substantially gaseous. The mid temperature ejector **180** also may be in communication with a mid temperature flash tank **270** and one or more mid temperature evaporators **280**. The mid temperature evaporators **280** may be evenly or unevenly sized to cover a certain capacity range and modulation. The first portion **260** of the flow **230** may enter the mid temperature ejector **180** at the motive inlet **110** as the motive flow. The flow of refrigerant **230** from the mid temperature evaporators **280** may enter the suction inlet **120** in a liquid state as the suction flow. The motive flow of refrigerant **230** thus may be accelerated and reduced in pressure upon leaving the outlet **150**. The flow of refrigerant **230** then may again be separated into vapor and liquid form in the temperature flash tank **270**. The vaporized refrigerant **230** may be returned to the mid temperature suction groups **220** via the mid temperature suction line heat exchanger **250** while the liquid flow may be sent to the mid temperature evaporators **280** and back to the mid temperature ejector **180**. Other components and other configurations also may be used herein.

A second portion **290** of the flow of refrigerant **230** from the gas cooler/condenser **240** may be routed to the low temperature ejector **220** of the low temperature cycle **210**. The second portion **290** of the flow of refrigerant **230** may first pass through a low temperature suction line heat exchanger **300**. The low temperature ejector **200** also may be in communication with a low temperature flash tank **310** and one or more low temperature evaporators **320**. The low temperature evaporators **320** may be evenly or unevenly sized to cover a certain capacity range and modulation. The second portion **290** of the flow of refrigerant **230** thus may enter the motive inlet **110** of the low temperature ejector **200** while the flow of refrigerant **230** from the low temperature evaporator **320** may enter at the suction inlet **120**. Again the mixed flow may be accelerated and reduced in pressure. The mixed flow thus leaves the outlet **150** of the low temperature ejector **200** and flows to the low temperature flash tank **310**. The vaporized portion of the flow of refrigerant **230** may flow through the low temperature suction line heat exchanger **300** and towards a number of low temperature suction groups **330** or compressors. The flow of refrigerant **230** then may be forwarded to the mid temperature flash tank **270** or directly back to the gas cooler/condenser **240**. The liquid portion of the flow of refrigerant **230** may pass through the low temperature evaporator **320** and back to the low temperature ejector **200**. The cycle then may be repeated.

The use of the ejectors **180**, **200** serves to recover pressure/work herein. The work recovered from the expansion process may be used to compress the vaporized refrigerant before entering into the compressors/suction groups. Accordingly, the pressure ratio of the suction groups (and thus the overall power consumption) may be reduced for a given evaporator pressure. The quality of the refrigerant also may be reduced. The overall number of pumps also may be reduced and/or eliminated.

FIG. **3** shows an alternative embodiment of a carbon dioxide refrigeration system **160**. In this example, the ejectors **100** may be positioned in a series configuration **340**. Specifically, a medium temperature cycle **350** and a low temperature cycle **360** may be positioned in a series configuration **340**. Other components and other configurations may be used herein.

The mid temperature cycle **350** may include the mid temperature suction groups **220**, the gas cooler/condenser **240**, and the mid temperature suction line heat exchanger **250** substantially as described above. In this example, however, the entire flow of refrigerant **230** may be directed to the mid temperature ejector **180**. The mid temperature ejector **180** also may be in communication with the mid temperature flash tank **270** and the mid temperature evaporator **280**. In this example, a first portion **370** of the fluid refrigerant **230** may be directed to the mid temperature evaporators **280** while a second portion **380** may be forwarded to the low temperature cycle **360**.

The lower temperature cycle **360** also may include the low temperature suction line heat exchanger **300** and the low temperature ejector **200** in communication with the low temperature flash tank **310** and the low temperature evaporator **320**. The low temperature cycle **360** also includes the low temperature suction groups **330**. The flow of refrigerant **230** thus flows first through the mid temperature cycle **350** and then through the low temperature cycle **360** before being returned to either the mid temperature flash tank **270** and/or the gas cooler/condenser **240**. Other components and other configurations may be used herein.

FIG. **4** shows an alternative embodiment of FIG. **2**. In this example, an evaporator **390** or an assembly of evaporators **390** in a parallel configuration are positioned between the outlet of the low temperature ejector **200** and the inlet of the low temperature flash tank **310**. Further, the flash tank liquid outlet is fed into the ejector suction port **120** in the low temperature cycle **210**. This alternative embodiment enables overfeeding of the evaporator coils with liquid such that they can have heat transfer performance enhancement.

FIG. **5** shows an alternative embodiment of the transcritical carbon dioxide based refrigeration system **160** of FIG. **3**. In this example, an evaporator **400** or an assembly of evaporators **400** in a parallel configuration are positioned in between the outlet of the low temperature ejector **200** and the inlet of the low temperature flash tank **310**. Further, the flash tank liquid outlet is fed into the ejector suction port **120** in the low temperature cycle **210**. This alternative embodiment also enables overfeeding of the evaporator coils with liquid such that they can have heat transfer performance enhancement.

It should be apparent that the foregoing relates only to certain embodiments of the present application and the resultant patent. Numerous changes and modifications may be made herein by one of ordinary skill in the art without departing from the general spirit and scope of the invention as defined by the following claims and the equivalents thereof.

I claim:

1. A system, comprising:

a gas cooler/condenser;

a first temperature cycle comprising:

- a first ejector configured to receive refrigerant through a motive inlet of the first ejector from the gas cooler/condenser;
- a first flash tank configured to receive refrigerant from an outlet of the first ejector;
- a first evaporator configured to receive refrigerant from the first flash tank, wherein refrigerant flows from the first evaporator to the first ejector through a suction inlet of the first ejector; and

first suction groups downstream the first flash tank; and a second temperature cycle comprising:

a second ejector configured to receive refrigerant;

a second flash tank downstream from the second ejector;

a second evaporator downstream from the second ejector; and

second suction groups downstream from the second flash tank;

wherein the gas cooler/condenser is configured to receive refrigerant from the first suction groups.

2. The system of claim **1**, wherein the first temperature cycle and second temperature cycle comprise a parallel configuration such that the motive inlet of the first ejector and a motive inlet of the second ejector are in parallel in relation to an outlet of the gas cooler/condenser.

3. The system of claim **1**, wherein the first temperature cycle and second temperature cycle comprise a series configuration such that a motive inlet of the second ejector is downstream from the outlet of the first ejector.

4. The system of claim **1**, wherein the system is a transcritical carbon dioxide refrigeration system.

5. The system of claim **1**, wherein the first temperature cycle further comprises a first suction line heat exchanger between the first flash tank and the first suction groups and between the gas cooler/condenser and the motive inlet of the first ejector.

6. The system of claim **1**, wherein the second temperature cycle further comprises a second suction line heat exchanger between the second flash tank and the second suction groups and between the gas cooler/condenser and the motive inlet of the second ejector.

7. The system of claim **1**, wherein the second evaporator is configured to receive refrigerant from the second flash tank and the second ejector is configured to receive refrigerant at a suction inlet from the second evaporator.

8. The system of claim **1**, wherein the second flash tank is configured to receive refrigerant from the second evaporator and the second ejector is configured to receive refrigerant at a suction inlet from the second flash tank.

9. The system of claim **1**, further comprising a carbon dioxide based refrigerant, wherein at least a portion of the carbon dioxide based refrigerant flows directly from the second suction groups to the gas cooler/condenser.

10. The system of claim **1**, further comprising a carbon dioxide based refrigerant, wherein a portion of the carbon dioxide based refrigerant flows through the first temperature cycle and an other portion of the carbon dioxide based refrigerant flows through the second temperature cycle.

11. The system of claim **1**, further comprising a carbon dioxide based refrigerant, wherein a portion of the carbon dioxide based refrigerant flows from the second temperature cycle to the first temperature cycle from the second suction groups to the first flash tank.

12. The system of claim **1**, wherein the first temperature cycle operates at a higher temperature than the second temperature cycle.

13. A method, comprising:

flowing a portion of a carbon dioxide refrigerant from a gas cooler/condenser to a first ejector;

accelerating the portion of the flow of the carbon dioxide refrigerant in the first ejector;

separating the portion of the flow of the carbon dioxide refrigerant into a vapor part and a liquid part at a first flash tank;

flowing the vapor part of the portion of the flow of the carbon dioxide refrigerant to a first suction group downstream from the first flash tank;

flowing an other portion of the carbon dioxide refrigerant from the gas cooler/condenser to a second ejector;

accelerating the other portion of the flow of the carbon dioxide refrigerant in the second ejector; and

separating the other portion of the flow of the carbon dioxide refrigerant into a vapor part and a liquid part at a second flash tank;

flowing the vapor portion of the other portion of the flow of the carbon dioxide refrigerant to a second suction group downstream from the second flash tank.

14. The method of claim **13**, further comprising:

evaporating the portion of the flow of carbon dioxide refrigerant at a first evaporator downstream from the first ejector; and

evaporating the other portion of the flow of carbon dioxide refrigerant at a second evaporator downstream from the second ejector.

15. The method of claim **14**, wherein evaporating the other portion of the flow of carbon dioxide refrigerant at the second evaporator comprises flowing the other portion of the flow of carbon dioxide refrigerant from the second evaporator to the second flash tank and then to a suction inlet of the second ejector.

16. The method of claim **14**, wherein evaporating the other portion of the flow of carbon dioxide refrigerant at the second evaporator comprises flowing the other portion of the flow of carbon dioxide refrigerant from an outlet of the second ejector to the second flash tank and then from the flash tank to the second evaporator.

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